

Earth Rotation Variation from Hours to Centuries

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The study of Earth rotation encompasses the complex nature of orientation changes, the excitation of these changes and their geophysical implications in a broad variety of areas. Earth system studies have embarked on a new era with the advent of highly accurate space geodetic techniques and the increasing availability of complementary geophysical data sets. Techniques utilized include laser ranging to the Moon and artificial satellites (LLR and SLR), very long baseline interferometry (VLBI) and the newly developing GPS technology. The measurements reveal minute but complicated changes of up to several parts in 10^8 in the speed of the Earth's rotation, corresponding to several milliseconds in the length of the day (LOD). Intercomparisons indicate that Earth rotation is now routinely determined at the 0.03 millisecond (ms) level for UT1 (approximately -1.4 cm at the equator) with higher accuracy being achieved in some cases. Many geophysically interesting variations are detectable at these levels.

Highly accurate observations of Earth rotation provide a unique and truly global measure of natural and man-made changes in the atmosphere, oceans, and interior of the Earth. The principle of conservation of angular momentum requires that changes in the Earth's rotation must be manifestations either of (a) torques acting on the solid Earth, or (b) changes in the mass distribution within the solid Earth, which alter its moment of inertia. Torques arise from angular momentum transfer between the solid Earth and the fluid regions (the underlying metallic core and the overlying hydrosphere and atmosphere) with which it is in contact. Changes in the inertia tensor of the solid Earth are brought about not only by internal stresses and the gravitational attractions associated with astronomical objects and mass redistributions in the fluid regions of the Earth, but also by processes that redistribute the material of the solid Earth, such as earthquakes, postglacial rebound, and mantle convection. Geodetic observations of Earth rotation changes provide insights into these geophysical processes, which are often difficult to obtain by other means.

These changes occur over a broad spectrum of time scales, ranging from minutes to millions of years, reflecting the fact that they are produced by a wide variety of geophysical and astronomical processes. Earth rotation, when studied in combination with other parameters such as global integrated atmospheric angular momentum (AAM) and the Southern Oscillation Index, allows new and unique insights into geophysical processes. From intercomparisons of AAM and LOD, we find that Earth rotation variations over time scales of a few years to days are dominated by atmospheric effects, with a dominant seasonal cycle and significant variability on the intraseasonal (40 to 50 day) time scale. Subdaily variations are largely due to ocean tidal effects. Variations on interannual time scales have been related to the El Niño/Southern Oscillation phenomenon. Torques between the core and mantle are the most probable cause for the longer-scale "decade" fluctuations in the LOD. Trends found on even longer time scales (the "secular" changes) are due to tidal dissipation torques, which produce a steady increase in the LOD at a rate estimated from ancient eclipse records to lie between 1 and 2 milliseconds per century. Contributions to LOD changes on the same secular time scale are also produced by internal sources, such as changes in the moment of inertia of the solid Earth resulting from the melting of ice after the last glacial maximum. Current activities will be reviewed; anticipated advances and prospects for the future will be highlighted,